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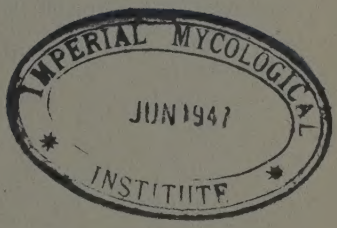

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MATHEMATICS

ON ORTHONORMAL SYSTEMS

By N. P. ROMANOFF

(Communicated by S. L. Soboleff, Member of the Academy, 25. III. 1944)

Throughout this paper the following notations are adopted: $\sum_{d/n}$ denotes that summation is extended over all divisors of n; $\mu(n)$ is the well-known Möbius' function, satisfying the relations

$$\sum_{d/n} \mu(d) = \begin{cases} 1 & \text{if } n = 1 \\ 0 & \text{if } n > 1 \end{cases}$$

and (n, m) is the greatest common divisor of n and m. In accordance with Möbius' inversion principle, from $a_n = \sum_{d/n} b_d \quad (n = 1, 2, 3, \ldots)$ follows $b_n = \sum_{d/n} \mu\left(\frac{n}{d}\right) a_d \; (n = 1, 2, 3 \ldots)$ and *vice versa*.

We shall need the following lemma: if $k < n$, $f(u)$ is an arbitrary function of a positive integral argument u, then $\sum_{d/n} \mu\left(\frac{n}{d}\right) f((k, d)) = 0$. To prove this, consider the operations A, B, S, S', E defined by

$$Af(n) = f((n, N)), \quad Bf(n) = \varepsilon\left(\frac{N}{n}\right) f(n), \quad Sf(n) = \sum_{d/n} f(d),$$

$$S'f(n) = \sum_{d/n} \mu\left(\frac{n}{d}\right) f(d), \quad Ef(n) = f(n)$$

where N is a fixed positive integer, $\varepsilon(u) = 1$ for all integral values of u, otherwise $\varepsilon(u) = 0$.

From Möbius' inversion principle follows that $S'S = SS' = E$. We have

$$SBf(n) = \sum_{d/n} \varepsilon\left(\frac{N}{d}\right) f(d) = \sum_{d/(n, N)} f(d) = Af(n), \; SB = AS, \; SBS^{-1} = A, \; S^{-1}A = BS^{-1}$$

further

$$S^{-1}Af(n) = \sum_{d/n} \mu\left(\frac{n}{d}\right) f((N, d)) = BS^{-1}f(n) = \varepsilon\left(\frac{N}{n}\right) \sum_{d/n} \mu\left(\frac{n}{d}\right) f(d)$$

Taking $N = k$ we get the lemma stated, for $\varepsilon(k/n) = 0$. In what follows the Hilbert space H is considered in the axiomatic form of Stone—Neumann.

Every sequence $f_1, f_2, \ldots$ of H is said to have D-property or, more precisely, D_g-property if $(f_n, f_m) = g((n, m))$, where $g(u)$ is a given function defined for all positive integral values of u. For every sequence $f_1, f_2, \ldots$ enjoying the above property, the sequence $\gamma_1, \gamma_2, \ldots$, where $\gamma_n = \sum_{d/n} \mu\left(\frac{n}{d}\right) f_d$, is orthogonal, *i. e.* $(\gamma_n, \gamma_m) = 0$ if $n \neq m$.

This fact can be established in the following way: for $k < n$

$$(\gamma_n, f_k) = \left(\sum_{d/n} \mu\left(\frac{n}{d}\right) f_d, f_k\right) = \sum_{d/n} \mu\left(\frac{n}{d}\right) g((d, k)) = 0$$

as follows from our lemma, and $(\gamma_n, \gamma_m) = 0$ if $m < n$, for γ_m is a linear combination of f_k with $k < n$. Hence the orthogonality follows, $m < n$ being no real restriction. The process of orthogonalization, according to E. Schmidt, coincides for sequences with the D-property with Möbius' inversion process which plays an important rôle in the theory of numbers. If

$$G(n) = \sum_{d/n} \mu\left(\frac{n}{d}\right) g(d) > 0 \qquad (n = 1, 2, 3, \ldots)$$

then $\psi_n = \frac{1}{\sqrt{G(n)}} \sum_{d/n} \mu\left(\frac{n}{d}\right) f_d$ are forming an orthonormal system. The author has constructed many examples of sequences with D_g-property for every $g(u)$ satisfying the conditions:

$$g(u) > 0, \quad g(a)\, g(b) = g(1)\, g(ab), \quad \sum_{k=1}^{\infty} \frac{1}{g(k)} < \infty$$

and for some others. If H is a separable space, we can find the sequences which, apart from the D-property, are satisfying the condition of completeness, *i. e.* such that for every $f \in H$ and every $\varepsilon > 0$ we can find $n, c_1, c_2, \ldots, c_n$ so that

$$\| f - c_1 f_1 - c_2 f_2 - \ldots - c_n f_n \| < \varepsilon.$$

From

$$\psi_n = \frac{1}{\sqrt{G(n)}} \sum_{d/n} \mu\left(\frac{n}{d}\right) f_d \tag{1}$$

and from Möbius' inversion theorem follows

$$f_n = \sum_{d/n} \sqrt{G(d)}\, \psi_d \tag{2}$$

Defining f_n^* as

$$f_n^* = \sum_{d/n} \frac{\mu(d)}{\sqrt{G(d)}} \psi_d \tag{3}$$

we have

$$(f_n, f_m^*) = \begin{cases} 1 & \text{if } (n, m) = 1 \\ 0 & \text{if } (n, m) > 1 \end{cases} \quad \text{for } (f_n, f_m^*) = \sum_{d/(n, m)} \mu(d).$$

From (1) and (3) we get $f_n^* = \sum k_n(d) f_d$, where $k_n(d) = \sum_{\delta/\frac{n}{d}} \frac{\mu(d\delta)\, \mu(\delta)}{G(d\delta)}$.

If $g(u)$ is a multiplicative function, *i. e.* if $g(a)\,g(b) = g(ab)$, we have

$$G(n) = g(n) \prod_{p/n} (1 - g(p)^{-1}), \qquad \frac{g(n)}{G(n)} \sum_{d/n} \frac{\mu(d)}{g(d)}\, g((d, m)) = \begin{cases} 1 & \text{if } (n, m) = 1 \\ 0 & \text{if } (n, m) > 1 \end{cases}$$

for every multiplicative $g(u)$ with $G(n) > 0$.

In this manner the author has got many arithmetical identities which can otherwise be proved only on a rather complicated combinatorial reasoning. Quite trivial identities are obtained, if the completeness of orthonormal sequences of H is considered in addition. Let us state without proof the following result which permits constructing sequences with D-property:

If $\omega(n) \gtrless 0$, $\omega(a)\,\omega(b) = \omega(ab)$, $\sum_{k=1}^{\infty} \omega(k)^2 = \sigma < \infty$, and $\alpha_1, \alpha_2, \ldots$ is an orthonormal system of H, then $f_1, f_2, \ldots$ where $f_n = \omega(n)^{-1} \sum_{k=1}^{\infty} \omega(k)\, \alpha_{kn}$, has D_g-property with $g(u) = \frac{\sigma}{\omega(u)^2}$.

We can prove, further, that if $\alpha_1, \alpha_2, \ldots$ are forming a complete orthonormal system of H, then $\psi_1, \psi_2, \ldots \psi_n = \frac{1}{\sqrt{G(n)}} \sum_{d/n} \mu\left(\frac{n}{d}\right) f_d$ is a complete orthonormal system of H.

I conclude with the following remark: if $G(n)$ is an arbitrarily given positive function and the elements of sequences $f_1, f_2, \ldots$ and $\psi_1, \psi_2, \ldots$ are linked up by the relations: $f_n = \sum_{d/n} \sqrt{G(d)}\, \psi_d$ $(n = 1, 2, 3, \ldots)$, then $\psi_1, \psi_2, \ldots$ is orthonormal if and only if $f_1, f_2, \ldots$ has D_g-property with $g(n) = \sum_{d/n} G(d)$. For a given $g(u)$ the sequence with D_g-property can exist if and only if $G(n) = \sum_{d/n} \mu\left(\frac{n}{d}\right) g(d) \geqslant 0$ $(n = 1, 2, 3, \ldots)$. The condition is sufficient, for with $G(n) \geqslant 0$, $f_n = \sum_{d/n} \sqrt{G(d)}\, \psi_d$ form such a system if $\psi_1, \psi_2, \ldots$ is an arbitrary orthonormal system of H. The condition is necessary, for if $f_1, f_2, \ldots$ is a D_g-sequence, then

$$\sum_{d/n} \mu\left(\frac{n}{d}\right) g(d) = (\gamma_n, \gamma_n) \geqslant 0, \quad \text{where } \gamma_n = \sum_{d/n} \mu\left(\frac{n}{d}\right) f_d.$$

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MATHÉMATIQUES

SUR LA MONOGÉNÉITÉ DANS L'ESPACE

Par V. S. FEDOROFF

(Présenté par N. N. Lusin, de l'Académie, le 22. V. 1944)

Désignons toujours dans ce qui suit par u et v ou P et Q des fonctions réelles des variables réelles x, y et z, uniformes et continues dans un domaine (ensemble ouvert et connexe de points de l'espace) D ainsi que leurs dérivées partielles jusqu'au second ordre. Nous allons écrire

$$u+iv\sim\vec{a} \tag{1}$$

à condition qu'on ait pour chaque point de D: $\nabla u=\nabla v\times\vec{a}$, $\nabla v=\vec{a}\times\nabla u$ et $\nabla u\times\nabla v$ est différent de zero, $\vec{a}$ étant un vecteur (fonction du point (x, y, z)) et $i^2=-1$.

Il est évident qu'une fonction $u+iv$ possède le vecteur correspondant $\vec{a}$ à condition (nécessaire et suffisante) suivante: en chaque point de D on a

$$\nabla u\cdot\nabla v=0,\quad (\nabla u)^2=(\nabla v)^2\neq 0 \tag{2}$$

Cette propriété (2) est équivalente à la propriété suivante de la fonction $u+iv$: un point quelconque M de D étant donné, il existent pour chaque rayon l issu de M deux rayons λ et t (issus de M), tels qu'on a:

1) $t\perp l$, $\lambda\perp l$

2) $\dfrac{\partial u}{\partial l}=\dfrac{\partial v}{\partial t}$, $\dfrac{\partial v}{\partial l}=\dfrac{\partial u}{\partial\lambda}$ (en ce point M) (∇u étant différent de zéro dans D).

Remarquons que les fonctions u et v qui possèdent la propriété (2) peuvent être harmoniques ou non dans D. Par exemple,

$$u=\sqrt{x^2+y^2},\quad v=z,\quad \text{ou}$$
$$u=x^2+y^2-z^2,\quad v=2z\sqrt{x^2+y^2},\quad etc.$$

Cela posé, l'auteur parvient à démontrer les théorèmes suivants:

1) La relation (1) étant donnée, on a

$$f(u+iv)\sim\vec{a},\quad f(u-iv)\sim-\vec{a}$$

pour toute fonction analytique $f(u+iv)$ holomorphe et ayant la dérivée non nulle pour les valeurs de $u+iv$ dans D.

2) Il résulte des relations

$$u+iv\sim\vec{a},\quad P+iQ\sim\vec{a}$$

qu'il existe un certain voisinage B de chaque point de D tel que $P+iQ$ est une fonction analytique de $u+iv$ dans B, holomorphe et ayant la dérivée non nulle pour les valeurs de $u+iv$ dans B.

3) Soit $u+iv \sim \nabla\varphi(x, y, z)$, c'est-à-dire on a en chaque point d'un domaine D:

$$\frac{\partial u}{\partial x}=\begin{vmatrix}\frac{\partial v}{\partial y} & \frac{\partial v}{\partial z}\\ \frac{\partial \varphi}{\partial y} & \frac{\partial \varphi}{\partial z}\end{vmatrix} \quad \frac{\partial u}{\partial y}=\begin{vmatrix}\frac{\partial v}{\partial z} & \frac{\partial v}{\partial x}\\ \frac{\partial \varphi}{\partial z} & \frac{\partial \varphi}{\partial x}\end{vmatrix} \quad \frac{\partial u}{\partial z}=\begin{vmatrix}\frac{\partial v}{\partial x} & \frac{\partial v}{\partial y}\\ \frac{\partial \varphi}{\partial x} & \frac{\partial \varphi}{\partial y}\end{vmatrix}$$

$$\frac{\partial v}{\partial x}=\begin{vmatrix}\frac{\partial \varphi}{\partial y} & \frac{\partial \varphi}{\partial z}\\ \frac{\partial u}{\partial y} & \frac{\partial u}{\partial z}\end{vmatrix} \quad \frac{\partial v}{\partial y}=\begin{vmatrix}\frac{\partial \varphi}{\partial z} & \frac{\partial \varphi}{\partial x}\\ \frac{\partial u}{\partial z} & \frac{\partial u}{\partial x}\end{vmatrix} \quad \frac{\partial v}{\partial z}=\begin{vmatrix}\frac{\partial \varphi}{\partial x} & \frac{\partial \varphi}{\partial y}\\ \frac{\partial u}{\partial x} & \frac{\partial u}{\partial y}\end{vmatrix}$$

(et ∇u est différent de zéro dans D).

Toutes les fonctions u, v et φ qui vérifient ces équations différentielles sont de la forme suivante: ou bien

$$\varphi = r = \sqrt{(x-\alpha)^2+(y-\beta)^2+(z-\gamma)^2}$$

α, β et γ étant des constantes réelles arbitraires, ou bien φ est une fonction linéaire de x, y, z. La fonction $u+iv$ est harmonique et de plus $u+iv=f(\zeta)$, où $f(\zeta)$ est une fonction analytique arbitraire et où l'on a: ou bien

$$\zeta = \frac{x-\alpha+i(y-\beta)}{z-\gamma+r} \quad \text{(dans le cas } \varphi = r\text{)}$$

ou bien

$$\zeta = ax+by+cz$$

a, b, c étant des constantes complexes arbitraires à condition $a^2+b^2+c^2=0$ (la fonction φ étant linéaire en x, y et z).

4) Les fonctions $u(x, y, z)$, $v(x, y, z)$ et $w(x, y, z)$ harmoniques dans un domaine et y vérifiant les équations

$$\nabla u \cdot \nabla v = 0, \quad \nabla v \cdot \nabla w = 0, \quad \nabla u \cdot \nabla w = 0, \quad (\nabla u)^2 = (\nabla v)^2 = (\nabla w)^2$$

sont nécessairement les fonctions linéaires des variables x, y et z.

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TECHNICAL PHYSICS

ON IMPROVING THE EQUATIONS OF ELECTROMAGNETIC FIELD

By P. L. KALANTAROV

(Communicated by V. F. Mitkevitch, Member of the Academy, 8. VI. 1944)

It is well known that if the relations between the quantities characterizing a magnetic field and an electric field are written in the usual form, they often include the coefficient 4π, although its presence cannot always be ascribed to natural causes.

As an example may serve the relation between electric displacement and electric force $D = \varepsilon E/4\pi$ or that between the magnetic permeability of a substance, its magnetic susceptibility and the magnetic permeability of a vacuum $\mu = 4\pi k + \mu_0$.

On the other hand, there are cases where the factor 4π is absent in spite of a sharply expressed spherical symmetry. Thus, for the capacity of a solitary sphere we have $C = \varepsilon R$. There are, moreover, expressions that suffer from lack of symmetry because some characteristics of the magnetic field are not defined quite identically with the corresponding characteristics of the electric field. To put an example, the energy referred to a unit volume of the field is $BH/8\pi$ in the case of magnetic field, and $DE/2$ in the case of electric field.

These facts attracted the attention of O. Heaviside. He was able to show that a system of units for measuring magnetic and electric quantities can be built up where the coefficient 4π will be assigned its natural place to reflect the presence of spherical symmetry, and at the same time a perfect symmetry between corresponding expressions for magnetic and electric fields will be obtained.

Yet the way toward this goal, as indicated by Heaviside, leads to such units as are connected with those deeply routed in the practice of scientific and technical measurements: namely, to the coefficients of the type $(4\pi)^m 10^n$, where $m = \pm\frac{1}{2}$, or $m = \pm 1$.

This circumstance precludes the possibility of a practical application of Heaviside's system of units.

On the other hand, improving the electromagnetic field equations according to Heaviside is a matter of great importance, and to carry it out there ought to be found a method suitable from a practical point of view.

In this connexion it was pointed out that the expressions in question could be rendered more convenient for practical use by decreasing 4π times the units of magnetic permeability and magnetic pole strength and increasing as many times those of dielectric constant, magnetic force, reluctance and magnetomotive force. Of the six units that had to be changed if one was to adopt this method, only two—the magnetic force and the magnetomotive force—are used in practice. This seemed to be a good course to take. And it was actually followed by the Measuring Units' Committee of the Academy of Sciences of the USSR. In 1938 they unanimously agreed upon proposing to add a fourth unit to the MKS system—the unit of magnetic permeability, equal to $10^7/4\pi$ of the magnetic permeability of a vacuum (1).

However, to have the coefficient 4π in the conversion factors is inconvenient even if no more than six units are affected by the transition to an improved system.

What is more, a partial modification of a system of units—confined to only six units—is apt to cause some confusion. To make this evident we shall consider the self-inductance L of some coil placed in a vacuum and made of a substance whose magnetic permeability is equal to that of the vacuum.

Let us have in an «unimproved» system of units, $L = \mu_0 F(l)$, where $F(l)$ is a function of the geometrical form of the coil and has the dimension of length.

Then in the improved system, in which the magnetic permeability is measured by a unit 4π times less, we shall have $L = \frac{\mu_0}{4\pi} F(l)$. Let us make use of the system MKSμ_0 having 1 metre for unit of length and 1 henry for unit of self-inductance. For the unit of magnetic permeability we adopt the terms ewing in the «unimproved» system, and raewing in the «improved» system, the relation between them being 1 ewing $= 4\pi$ raewings.

Let $F(l) = 10$ metres. Then, taking into account that $\mu_0 = 10^{-7}$ ewings $= 4\pi 10^{-7}$ raewings, we shall have:

$$L = \mu_0 F(l) = 10^{-7} \text{ ewings} \times 10 \text{ metres} = 10^{-6} \text{ henry}$$

$$L = \frac{\mu_0}{4\pi} F(l) = \frac{4\pi 10^{-7} \text{ raewings} \times 10 \text{ metres}}{4\pi} = 10^{-6} \text{ henry}.$$

From this it follows that

$$1 \text{ henry} = 1 \text{ ewing} \times 1 \text{ metre}$$
$$1 \text{ henry} = 1 \text{ raewing} \times 1 \text{ metre}$$

We have here two obviously incompatible relations. The reason of our failure to obtain a consistent result upon the transition to the improved system is this.

Decreasing 4π times the numerical coefficient in the expression for L and increasing as many times the numerical value of μ_0 has left the value of self-inductance unaltered. Yet while the unit of measurement on the left-hand side—henry—has thus suffered no change, that on the right-hand side has become 4π times smaller, because the unit of magnetic permeability has been decreased as much.

Clearly our equation cannot properly be improved by changing only a part of the units of the system.

However, the improvement can be carried out while leaving the system of units unchanged altogether. To do so it will suffice to change the notions of the above six quantities instead of changing the units adopted for their measurement. Namely, magnetic permeability and magnetic pole strength can be taken to be magnitudes 4π times greater than is generally agreed upon now, while dielectric constant, magnetic force, reluctance and magnetomotive force can be understood to mean 4π times lower quantities as compared to their present magnitudes.

If, for instance, the ratio of $4\pi D$ to E has been assumed thus far to represent the dielectric constant, we can now define this quantity as the ratio of D to K.

Similarly instead of taking for the source of a magnetic flux Φ a magnetic pole $m = \Phi/4\pi$, we can suppose this flux to be emitted by a mass equal to it in magnitude.

In order to show that the relations we are interested in can really be improved by changing the definitions of certain quantities, we shall consider by way of example the field created by an isolated magnetic pole m in a medium with magnetic permeability μ.

In the ordinary unimproved form

$$H = \frac{1}{\mu} \frac{m}{r^2}$$

Putting $H = 4\pi H'$, $\mu = \mu' / 4\pi$, $m = m' / 4\pi$, we get

$$4\pi H' = \frac{4\pi}{\mu'} \frac{m'}{4\pi r^2}$$

or

$$H' = \frac{1}{\mu'} \frac{m'}{4\pi r^2}$$

The presence of 4π in the formula for H' is only natural, since in the case considered the field has spherical symmetry.

This method of bringing the equations into a suitable form appears to be simple and convenient, and there is no need to change the units of measurement.

It should be emphasized that whether the equations are written in the usual or in the improved form, the units of measurements can be determined from the respective dimension formulae, which are known to contain no numerical coefficients.

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GEOPHYSICS

A METHOD OF MEASURING THE CONCENTRATION AND THE PARTICLE SIZE OF NATURAL AEROSOLS

By J. Z. SEIDENBERG

(Communicated by B. G. Fessenkow, Member of the Academy, 19. IV. 1944)

All the methods of measuring the concentration and particle size of natural aerosols in use up till now are too complicate and can be carried out only in the laboratory.

In 1942 V. F. Litvinov proposed the idea of constructing a portable field apparatus for measuring the concentration and particle size of various aerosols under the natural conditions in which they exist without precipitation. This idea has been brought to life by the author of the present paper in collaboration with Prof. V. F. Litvinov at the Institute of Astronomy and Physics of the Kazakhstan branch of the Academy of Sciences of the USSR.

This instrument is an ultramicroscope which differs from the well-known Zigmondi—Sidentopf system only in the manner in which the particles are illuminated: instead of being illuminated from one side, they are illuminated all along their generatrix, which makes the light dispersed by the particles many times brighter. As may be expected, this method of illumination increases the resolving power of the apparatus, which is an essential and positive feature distinguishing it from all former models. Practically, particles in Brownian movement can be easily observed by the light of an 8 V electric lamp of 21 W. The dark ground was formed by using the same principle as in the Zeiss dark field condenser. The central rays of the light flux falling upon the Abbé illuminater were cut out by placing two diaphragms, one in front of and the other behind the lower lens. It was found very convenient to remove the front-lens, since this lens shortens the focus of the illuminator and limits the freedom of setting a pan in position for observation. The pan is a hollow brass cylinder with two tubes for letting the sample in and out, with a top and bottom base and with well polished round glasses. The metallic surface of the pan is well blackened inside and out. The working dimensions of the pan are: cylinder bore, 6 mm; height, 2 mm; bore of the inlet and outlet tubes, 1 mm. The pan is made of two parts joined with screws for convenience in cleaning the glass surfaces from time to time. The optics of the microscope are as follows: a Zeiss microluminar with $f = 36$ mm as the objective, a GOMZ No. 23 orthoscopic 17 × ocular and a Huygens 10 × ocular of the same make, with an ocular scale, one division of which represents 0.0294 mm. The 17 × ocular has a diaphragm which limits the field of vision to 0.785 mm. The field apparatus is to be constructed with a number of interchangeable diaphragms. This is necessary in order to be able to adjust the field of vision so that, irrespective of the concentration of the test aerosol, the observer should not have to count more than four or five particles at a time.

To measure the concentration and the particle size of the test aerosol the apparatus is switched with an alternating current circuit or connected to an accumulator battery, which lights up the illuminator and sets an electric suction fan into motion. Then the top is turned 180° to let the aerosol be sucked into the pan.

1. Concentration Measuring. The observer sets in place the 17× ocular and counts the number of diffraction images of particles, well defined on the dark ground of the apparatus. The concentration of the test aerosol is found by calculating the mean concentration per determination (out of 100 determinations) and then reducing it to unit volume. The formula used in the calculation is:

$$rk_{\text{mean}} = \frac{M}{24.94 \cdot 10^{-5}} \text{ particles/cm}^3$$

where M is the mean number of particles per determination (out of 100 determinations); $24.94 \cdot 10^{-5}$ cm, the volume of the work space of the apparatus, which is determined by the diameter of the field of observation and the focal depth of the instrument's optic system.

2. Particle Size Determination. The observer sets in place the 10 × ocular and measures the free falling time of the diffractional images of particles past the ocular scale by means of a stop-watch. The particle size is then calculated by Stokes' law. In measuring natural aerosols we assumed the density of the solid phase ρ to be 2 g/cm^3, which approximately equals the density of natural dust of mineral origin. As a result, the relation between the size of the particle and its velocity on a path of 0.294 mm in our apparatus was found to be:

$$r = 3.48 \cdot 10^{-4} \sqrt{1/t} \text{ cm}$$

where t is the time in seconds required for a particle to fall 0.294 mm.

After measuring the velocity of falling particles in 5—6 samples of air, the observer determines the individual velocities of 40 to 60 particles (depending on the concentration) and thence the mean particle size of theaerosol under test. Counting the brightly lighted particles on a dark background and determining the velocity of their fall past the ocular scale of the instrument is not difficult, and this work can be done by any observer without any preliminary training.

In order to appraise the work of our apparatus we have made 4500 control determinations of concentration and about 1000 determinations of the particle size of aerosols, which were doubled in time and location with the Owens apparatus. In order to eliminate any subjective error, all the determinations were made alternately by two observers, after which the results were compared with those obtained with the Owens apparatus. For this comparison we calculated the correlation coefficient r which for aerosol concentration determinations with these two apparatuses was found to be: $r = +0.704 \pm 0.084$.

It was found that the absolute value of the aerosol concentration measured by the new apparatus was, on the average, three times as high as that given under identical conditions by the Owens apparatus. This shows the limited possibilities of the Owens apparatus, and the unfittedness of the precipitation method for measuring the concentration of aerosols. Particle size distribution curves plotted from the data obtained from these two apparatuses were almost identical.

Conclusions. 1. An apparatus has been constructed for measuring the concentration and size of particles in aerosols in the conditions under which they normally exist, *viz.* in suspension.

2. The method of illumination used, as described, increases the apparatus resolving capacity, which gives it a great advantage over all former models.

3. The working range of the apparatus is very wide, extending from particles subject to the Brownian movement up to particles several microns in diameter.

4. Determinations and calculations when using this newly constructed apparatus take minutes to do instead of hours, as required when working with the Owens apparatus, and can be made by any observer without preliminary experience.

5. The apparatus is portable and can be widely used in expedition work.

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PHYSICAL CHEMISTRY

ON THE PHOSPHATING OF ZINC

By A. P. SIMAKOVSKY and V. I. WULFSON

(Communicated by Wl. A. Kistiakowsky, Member of the Academy, 16. III. 1944)

Steel and cast iron are phosphated in solutions of dihydro-orthophosphates of iron, manganese and zinc. Most widely employed is a preparation containing phosphates of manganese and iron which forms a film that satisfies the practical requirements (1).

For ordinary phosphating mono-substituted orthophosphate of zinc is rarely employed: at present it is employed for phosphating with the simultaneous application of an alternating current (2).

When zinc is present in the phosphating preparation, formation of the phosphate film proceeds according to the following mechanism:

$$Fe + Zn(H_2PO_4)_2 = FeHPO_4 + ZnHPO_4 + H_2 \quad (1)$$

$$Fe + FeHPO_4 + ZnHPO_4 = Fe_2Zn(PO_4)_2 + H_2 \quad (2)$$

$$Fe + 2ZnHPO_4 = FeZn_2(PO_4)_2 + H_2 \text{ } etc. \quad (2')$$

The process proceeds in a similar manner with ferro-manganese phosphate (3).

One of the most valuable properties of phosphate film is its capacity to fulfil the rôle of a ground under paint. Research has shown that the resistance to corrosion of iron that has been phosphated and then painted is approximately 10 times as great as that of iron that has been painted over a usual ground (4).

It is known that those protective or decorative paint and varnish coatings which are generally good protectors of iron, prove to be a failure on a zinc surface (5). Research has shown that it is difficult to select varnish or paint coatings that adhere well to zinc and protect it satisfactorily (6).

The aim of the present investigation has been to explore the possibility of obtaining satisfactory phosphate layers on zinc from a solution of ferro-manganese phosphate.

The properties of this phosphate layer as a ground under paint on zinc have also been investigated.

From the point of view of the phosphating process itself, one might have anticipated that a common Mn—Fe phosphate should be suitable for phosphating zinc,

since the formation of the phosphate layer proceeds according to the scheme:

$$Zn + \frac{Mn}{Fe}(H_2PO_4)_2 = ZnHPO_4 + \frac{Mn}{Fe}HPO_4 + H_2 \quad (3)$$

$$Zn + ZnHPO_4 + \frac{Mn}{Fe}HPO_4 = Zn_2\frac{Mn}{Fe}(PO_4)_2 + H_2 \ etc. \quad (4)$$

A phosphate bath was prepared from a Mn—Fe phosphate manufactured at the «Krasny Khimik» plant. The concentration of the phosphating solution corresponded to 30 «points», *i. e.* 30 ml of a 0.1 *N* solution of NaOH were used up in titrating 10 ml of the solution in the presence of methyl-orange as indicator, which is a generally accepted norm for the phosphating of iron articles.

Zinc plates 30 × 15 × 3 mm in dimension were phosphated. The surface of the samples was previously treated with emery paper. Before phosphating, the samples were freed from grease in a 5 per cent solution of soda at room temperature and washed under a jet of tap water, and then were immediately immersed in the phosphating bath. The bath was kept at a temperature of 96—98° C. Immediately after immersion of the samples into the bath violent evolution of hydrogen began which lasted for 5—6 min.; afterwards the process quieted down considerably. After the evolution of hydrogen ceased, the samples were kept in the bath for another 15 min., so that the total phosphating time amounted to 40 min.

The samples were then removed from the bath, washed with hot distilled water and immediately placed in a drying oven kept at a temperature of about 50°C. After phosphating, the samples showed an increase in weight amounting to 40—50 g per square meter, which is higher than that for phosphated iron samples, where the increase in weight amounts to about 30 g per square meter (7).

The phosphated zinc samples had a finely crystalline surface yellowish, light-brown in colour.

Part of the phosphated samples were painted with common paint.

Corrosion tests were carried out in a 3 per cent solution of NaCl in a spindle apparatus. The following samples were tested: painted zinc, phosphated zinc and phosphated zinc subsequently painted.

The tests lasted for 400 hours: 200 hours with stirring, while the rest of the time (periodically) the samples lay quietly in the solution. The results are given in the table.

Sample	Loss in weight of samples, g/m² hour						Description of samples
	Sample number					Mean	
	1	2	3	4	5		
Zinc	0.154	0.138	0.146	0.134	0.169	0.148	Samples covered almost entirely with minute pits; in some places these are rather deep. Oxide is dense
Painted zinc	0.056	0.047	0.040	0.039	0.043	0.045	At individual spots the layer of paint puffed up and pealed off slightly. The paint came off almost completely
Phosphated zinc	0	0	0	0	0	0	The phosphate film was completely intact and did not change
Phosphated zinc subsequently painted	0	0	0	0	0	0	The layer of paint over the phosphate was completely intact and did not change

Conclusions. 1) It has been shown that one may obtain a phosphate film on zinc using an ordinary ferro-manganese phosphate.

2) The resistance to corrosion of zinc samples with a phosphate film in 3 per cent NaCl is considerably higher than the resistance to corrosion of unprotected zinc samples and zinc samples covered by common paint.

3) A phosphate layer on zinc is a good ground under common paint, eliminating the detrimental influence of zinc on the paint.

4) This latter conclusion may be extended to zinc plated samples as well.

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PHYSICAL CHEMISTRY

THE SHAPE OF A FLAME NEAR THE WALLS

By D. A. FRANK-KAMENETZKY

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At a distance from the walls the shape of the flame front is determined by Michelson's cosine law (1). In the immediate vicinity of the walls, within the laminar underlayer, where the rate of gas flow falls to zero, both the cosine law and the very concept of the fundamental velocity of flame propagation become inapplicable. If these concepts could be applied for every layer at any distance from the wall, the flame front would become infinitely extended, which is impossible.

However, the concept of the fundamental velocity of flame propagation is based upon the assumption that heat transfer takes place in only one direction—normal to the flame surface. It is precisely this assumption that makes it possible to treat the problem as unidimensional, and to compute the velocity of flame propagation.

It is obvious that this fundamental assumption does not always hold. In the immediate vicinity of the wall heat transfer in a direction parallel to the flame surface becomes an essential factor. In order to analyse the phenomena taking place under these circumstances it is necessary to develop a multi-dimensional theory of flame propagation.

Without going into the details of such a theory here, we shall show how the angle at which the flame front approaches the wall may be found, proceeding from elementary considerations. In this treatment we shall assume that the temperature and the temperature gradient in the flame zone remain practically constant as the latter approaches the wall. This assumption follows naturally from the general theory of flame propagation (2), according to which in view of the quite marked exponential dependence of reaction rates upon temperature the rate of reaction at temperatures lower than the maximum flame temperature may be disregarded. Therefore the region in which the combustion processes take place may be divided into two zones: a preheating zone and a reaction zone. In the preheating zone we disregard the heat evolved as a result of reaction, while in the reaction zone we disregard the heat transferred by convection by the gas flow.

The temperature in the reaction zone may be assumed, as a first approximation, to be always equal to the theoretical temperature of combustion. As was shown by Zeldovich in his theory on the limits of flame propagation (3), this temperature may, as a result of heat conductance, be decreased only by a value of the order of RT_m^2/E (where T_m is the maximum flame temperature, E is the energy of activation for the chemical reaction of combustion, and R is the gas constant), which is insignificant in comparison with the total heat intensity in the flame zone. Hence it follows that the flame front cannot gradually «degenerate», and its temperature decrease upon approaching the heat conducting walls. The flame

front must either reach the wall maintaining a practically constant temperature close to the theoretical temperature of combustion, or break up completely before reaching the wall.

Proceeding on these considerations we may place the component of the temperature gradient in the direction of the flame front equal to zero in the reaction zone. In the preheating zone this component will already be different from zero, and it is herein that the difference between this and the unidimensional theory lies.

The component of the temperature gradient normal to the flame surface may be found from the general theory of flame propagation [2]. According to this theory, in the unidimensional case the heat flow from the flame zone is expressed as follows:

$$q_1 = c\rho w (T_m - T_0) = -\lambda (\nabla T)_1 \qquad (1)$$

where c is the specific heat of the combustible mixture; ρ is its density; λ is the thermal conductivity; T_0 and T_m are the initial temperature of the combustible mixture and the maximum temperature of combustion, respectively; and w is the fundamental velocity of propagation of the flame.

Whence for the component of the temperature gradient normal to the surface of the flame front we get:

$$(\nabla T)_1 = -\frac{w}{\varkappa}(T_m - T_0) \qquad (2)$$

where $\varkappa = \lambda / c\rho$ is the temperature conductivity of the combustible mixture.

On the basis of what has been said above, we assume that the structure of the reaction zone does not change essentially upon approaching the wall, so that $(\nabla T)_1$ may be assumed to have the same value at the wall as in the unidimensional theory.

On the other hand, if the conditions for heat transfer through the wall are known, we may write the following expression for the heat flow in a direction perpendicular to the wall:

$$q_2 = \alpha (T_m - T_0) = -\lambda (\nabla T)_2 \qquad (3)$$

where α is the coefficient of heat transfer through the wall (not from the gas to the wall). We shall assume that the heat flow q_2 is positive when it is directed from the gas to the wall, and that the temperature of the surroundings is equal to the initial temperature of the combustible mixture T_0. Whence we get the following expression for component of the temperature gradient normal to the wall:

$$(\nabla T)_2 = -\frac{\alpha}{\lambda}(T_m - T_0) \qquad (4)$$

Let us denote by φ the angle between the flame surface and a perpendicular to the wall, defining it to be positive when it contains the initial mixture, and negative when it contains the combustion products (Figs. 1 and 2). Then the following relation should exist between the components of the vector ∇T:

$$(\nabla T)_2 = -(\nabla T)_1 \sin \varphi \qquad (5)$$

Substituting the values of $(\nabla T)_1$ and $(\nabla T)_2$ from (2) and (4) into (5), we get:

$$\sin \varphi = -\alpha / c\rho w \qquad (6)$$

One may draw an interesting qualitative conclusion from the above formula. When the wall is cooled ($\alpha>0$), the flame always approaches it at a negative angle (as shown in Fig. 2). When the wall is heated from outside or when it liberates

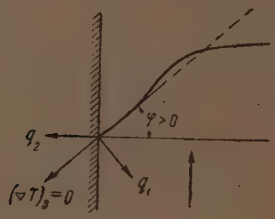

Fig. 1

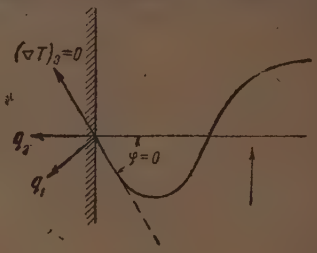

Fig. 2

heat as a result of a catalytic reaction ($\alpha<0$), the flame approaches it at a positive angle (as shown in Fig. 1). When the wall is thermally neutral, the flame approaches it at a zero angle.

The last deduction could be drawn without a quantitative analysis by the following simple qualitative considerations. The heat flow from the flame zone should be directed to the unburnt gas and not to the combustion products. In the vicinity of the point of intersection of the flame surface and the wall, the direction of this heat flow should coincide with the direction of the heat exchange between the gas and the wall. In the case of a cooled wall, where the heat exchange is directed from the gas to the wall, the above conditions may be fulfilled only if

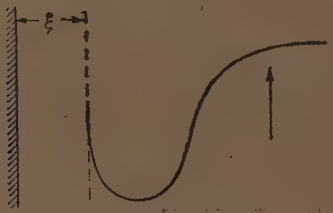

Fig. 3

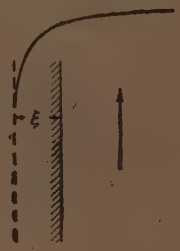

Fig. 4

the initial mixture is present between the flame and the wall (as shown in Fig. 2). In the case of a heated or catalysing wall, the products of combustion should be present between the flame and the wall (as shown in Fig. 1). When heat conductance is very intensive, *i. e.* when $\alpha > c\rho w$, the flame will not reach the wall at all: the flame front will be disrupted before it crosses the wall.

When the wall is perfectly cold and the intensity of heat conductance is infinitely great, the flame front will be established as shown in Fig. 3, and will break at such a distance from the wall that the heat transfer through the gas layer separating it from the wall will satisfy the condition

$$\alpha = c\rho w \tag{7}$$

Since for heat transfer in a laminar underlayer

$$\alpha = \lambda/\delta \tag{8}$$

where δ is the thickness of the gas layer, we shall obtain for the distance from the flame front to the wall in this limiting case:

$$\delta = \varkappa/w = \xi \tag{9}$$

where ξ is the thermal thickness of the flame zone, determined from the condition

$$(\nabla T)_1 = (T_m - T_0)/\xi \qquad (10)$$

as distinct from the chemical thickness of the zone defined by the condition

$$\xi' = w\tau \qquad (11)$$

where τ is the reaction time.

The quantities ξ and ξ' differ from each other by a dimensionless factor depending upon the reaction kinetics, which may be found from the general theory of flame propagation ([2]).

The shape of the front at a cold wall (Figs. 2 and 3) is quite complex and unnatural (even though it seems to accord with observation).

It is natural that the flame, whenever it has the possibility of doing so, comes out to the end of the tube and is established outside of it again at a distance equal to the thermal thickness of the zone (Fig. 4). It is readily seen that the location of the flame shown in Fig. 4 is exactly equivalent to its location in Fig. 3 from the point of view of the relation between the components of the vector ∇T.

The fact that the Bunsen flame is located outside the tube, in accordance with Fig. 4, and that the distance from the flame front to the wall is of the order of the thermal thickness of the zone, has already been noted by Khitrin ([4]), but the explanation he gave is hardly adequate.

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BIOCHEMISTRY

ENZYMIC TREATMENT OF BRAN AS A MEANS OF INCREASING ITS DIGESTIBILITY

By A. I. OPARIN, Corresponding Member of the Academy, N. I. PROSKURIAKOV and L. A. ZEITLIN

The use of flour ground from whole grain involves a number of difficulties because of the considerable quantity of poorly digestible bran which impairs the quality of the resulting bread. Yet, the bran particles represent a highly valuable product. Being largely made up of the aleuronic layer and coat of the seed, bran contains important amounts of proteins, in which it is relatively higher than the endosperm itself. And what is especially important, the composition of the bran proteins favourably compares with that of the endosperm proteins because of the amino-acids which make them comparable with proteins of animal origin. Thus, according to Jones and Gersdorff (1), the globulin fraction of bran contains up to 12 per cent lysin, while the albumin fraction contains 4.76 per cent tryptophan and 4.51 per cent lysin. The content of histidin and cystin is also a rather high one. According to recent studies, in particular to data by Light and Frey (2), it is just its being low in lysin that should be taken to account for the deficiency of white bread. It is no less important that considerable reserves of vitamins of the B group are concentrated in the bran, inclusive of riboflavin, nicotinic acid, tiamine, *etc.*

It has recently been found by Chick (3) that the nutritive value of the proteins contained in bread made with white flour is inferior to that of bread prepared with the so-called «national wheat-flour» (85 per cent output), while the latter is inferior in this respect to flour ground of a whole grain.

It should be pointed out here that in connexion with the World War there appeared a large number of papers dealing with the digestibility and biological value of flour ground from unhusked grain (4–6).

The utilization of bran in baking industry encounters important difficulties. however, for the enzymes of the digestive canal find no direct access to the proteins of the bran which are enclosed in very thick cellular walls of the aleuronic layer. Quite a number of methods — part of them patent — are available in literature, which make it possible to «refine» the bran, either by opening or by loosening those thick membranes. All these methods have largely been based upon purely mechanical treatments, occasionally upon treatments with enzymes, or upon the two treatments combined. One had also recourse to a mere heating of the bran, but its nutritive value has been found to be reduced if exposed to temperatures higher than 100° C, as has newly been reported by Borgström (7).

At the suggestion of the State Planning Committee, the Biochemical Institute of the Academy of Sciences of the USSR found itself facing the problem: to find a method for producing with whole-grain flour bread of as high a nutritive value as possible, by increasing the assimilation of bran.

With this aim in view as far back as in 1941 a method was developed at this Institute under the guidance of A. I. Oparin. The method implied a separate treatment of the bran and farinaceous part of the grain, which permits of a more complete and rational utilization of the bran in baking industry. According to this method the bran was first subjected to boiling, and then to saccharification and leavening with the aid of various lactic acid bacteria. The very first experimental lots of bread prepared under laboratory and industrial conditions, under collaboration of the All-Union Scientific Institute of Baking Industry (senior scientific worker B. G. Sarychev) showed the advantage of such separate treatment. This was clearly manifest both in the external appearance of the produce, and in its nitrogenous substances being more readily digested by the pepsin.

Test lots made with flour of 72 per cent output with an addition of bran treated according to the method here described, revealed in all cases a better quality of the inner part of the bread, a considerable increment in the output of bread by volume (up to 20 per cent), and an appreciable increase in the output of bread, as compared to the control in which dry bran was used.

The biochemical principle of the treatment remained obscure, however, for the factors responsible for the alterations observed were not yet discovered.

Our subsequent work consisted in finding out such conditions of bran treatment as would contribute to a maximum digestibility of the nitrogenous complex. The degree of digestibility was estimated according to the increment in water-soluble nitrogen exposed to a short-lived treatment with pepsin. The biochemical characteristic of the bran tested by us was as follows (in per cent to dry weight):

Total nitrogen	2.63	Monoses+saccharose	5.59
Starch	21.35	Fats	4.54
Cellulose	8.93		
Pentosans	23.63	Ash	5.26

Several preliminary procedures of boiling and saccharification of bran were put to test, in order to select those of them which would permit of a maximum accumulation of sugars and water-soluble nitrogen. In all cases a greater portion of the bran was poured over with some boiling water in order to make the starch form a paste. After the temperature was reduced to 65° C, the rest of bran was added (at the amount of 15 per cent) and the mixture was kept at this temperature during 2 hours. The content of residual starch was thus reduced to 6 per cent to the initial content, while the content of maltose-like carbohydrates and dextrins increased correspondingly; the content of water-soluble nitrogen made up no more than 24.7 per cent to total nitrogen.

The next procedure consisted in steeping the bran during 3 hours at a temperature of 40° C with a papain preparation taken at a ratio of 0.05 per cent by weight. After this the enzymes were inactivized by heating at a temperature of 80—90° C, followed by a saccharification with an amount of bran equal to that used in the previous run. In this experiment the water-soluble nitrogen was found to increase considerably (by about 17 per cent, *i. e.* more than in the previous run). The carbohydrate complex displayed about the same variations as in the first run. Thus, the two experiments went to confirm the possibility of increasing the water-soluble fraction of nitrogen at the expense of proteolysis only.

In the third run of bran pre-treatment a preparation of «fungal malt» was applied, consisting of a dried and fine-ground mycelium of *Aspergillus oryzae* 3 days old, taken together with the bran medium in which it was grown. The bran mash was prepared in the following way. After having treated the bran with boiling water in the usual manner and cooled it down to 55° C, the mixture was added fungal malt at a ratio of 5 per cent by weight, after which saccharification was carried on during 2 hours in one run and 22, in another.

The characteristic of the carbohydrate fraction of bran mash saccharified with fungal malt testifies of a deep process of saccharification (Table 1).

Table 1

	Monoses	Saccharose	Maltose-like sugars and dextrins
	in per cent to dry matter		
Saccharified during 2 hours	14.9	2.8	31.3
Saccharified during 22 hours	20.1	2.8	34.4

Such a considerable increase in monoses and carbohydrates of the type of maltose and dextrins seems to be due to the fact that along with the starch the enzymes of *Aspergillus oryzae* affect also the hemicelluloses and pentosans of the cellular walls; this may contribute to a liberation of the proteins enclosed in the sparingly permeable cells of the aleuronic layer.

Experiments made with the purpose to determine the increment in water-soluble nitrogen in the case of fungal malt went to confirm this assumption. The experiments were run at two temperature optima: first, after being converted into paste in the usual manner, the bran mash was cooled to 50° C and allowed to stay during 2 hours at this temperature, optimal for the action of proteases, upon which it was allowed to stay at a temperature of 55—57° C, in order to obtain better saccharification. Under the experimental conditions described the content of water-soluble nitrogen proved equal to 48.6 per cent to total nitrogen. In this way the latter run has been found to be the most efficacious, in so far as along with an extremely high rate of saccharification an intense proteolysis was also observed, which was a most essential condition for the subsequent procedure, *viz.* that of leavening.

In order to leaven the bran mash 2-day-old cultures of *Bacillus Delbrückii* were added to it at a ratio of 10 per cent by weight. The fermentation proceeded during 19—20 hours at a temperature of 50° C, after which the changes that took place in the content of the water-soluble nitrogenous fraction were evaluated. At the same time a control test was carried out with water-soluble nitrogen in the bran mash directly upon addition of the culture, *i. e.* omitting the stage of leavening.

In all cases this procedure resulted in a relatively small increment in water-soluble nitrogen (by about 6—7 per cent to total nitrogen). The test involving leavening made us assume that the effect of lactic acid bacteria is to contribute to a certain extent to the accumulation of water-soluble nitrogen.

The ultimate object of the work was to find out the effect of the treatments here described upon the digestibility of the bran with pepsin. Corresponding experiments were arranged involving both direct testing of bran, and testing of the bread prepared under addition of the treated bran. The concentration of pepsin and hydrochloric acid was 0.2 per cent with all experimental mixtures; time of digestion, 3 hours; temperature, 38—40° C. Two parallel control tests were also run: on bran mash with inactivized pepsin, and with a solution of inactivized pepsin together with the bacterial culture. The results of the digestion of treated bran with pepsin are summarized in the Table 2, the respective controls being subtracted in all cases.

From Table 2 it may be seen that the fermentating treatment with fungal malt resulted in a higher digestibility as compared to that brought about by self-saccharification. The large increment in water-soluble nitrogen should in this case be put down both to the direct effect of the proteases of *Aspergillus oryzae*, and to that of certain enzymes of the type of hemicellulase or even cytase, which might have affected the thickened cellular membranes and created conditions optimal for the action of the digesting enzymes, in particular, of pepsin, upon the proteins of the bran.

Table 2

Effect of Pre-Treatment upon Digestibility of Bran as Evaluated According to Increment in Water-Soluble Nitrogen[1]

	Bran treated with boiling water and allowed to saccharify		Bran treated with boiling water and saccharified with fungal malt	
	not leavened	leavened	not leavened	leavened
Water-soluble nitrogen in mg per 100 ml of filtrate	56.64	71.22	89.8	94.3
in per cent to total nitrogen	43.70	54.10	68.3	71.4

Further experiments involving the application of similar methods of bran treatment to the baking industry are presently in progress at the Experiment Station of the 1st Moscow Trust of Baking Industry, various kinds of flour being tested.

Thus, with the aid of the method described, by using the bran and farinaceous portions of grain separately, it is possible along with a certain economy to attain also most important qualitative improvements in the baking industry. The digestibility of the bran particles that usually are but poorly assimilated is also increased, which is most promising with respect to the improvement of the quality of bread made with whole-grain flour, or with flour giving high outputs.

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GEOLOGY

ON THE STRATIGRAPHY OF THE QUATERNARY DEPOSITS OF THE TAIMYR DEPRESSION

By V. N. SAKS

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The Quaternary deposits in the Taimyr depression* form, particularly in its western part, a continuous cover up to 100—200 m thick. Their bottom, even at the edge of the Central Siberian tableland, particularly in the valley of the Norilka River and on the Yenissei, in the regions of the Ust-Yenissei port and Dudinka, descends 45—75 m below the level of the rivers. This justifies the assumption that at the beginning of the Quaternary period the river network was about 70 m deeper than its present level, and that the sea level lay correspondingly lower, too. At definite periods the base level of erosion might have sunk lower still, since in two holes at the Ust-Yenissei port the Quaternary sands have been found to lie 150 m below the level of the Yenissei. According to their mineralogical composition the Quaternary rocks markedly differ from the older deposits of the depression in a predominance of pyroxenes (up to 33 per cent grains of the 0.01—0.1 mm fraction). This is due to an erosion of the rocks of the trap complex on the Central Siberian tableland and in the Byranga Mountains. No erosion seems to have taken place until the Quaternary period, since the pre-Quaternary (Mesozoic) deposits in the depression hardly contain any pyroxenes. Along with trap-minerals Quaternary sediments contain large amounts of minerals whose origin is alien to traps (quartz, acid plagioclases; in the heavy fractions — epidote, amphiboles, ore minerals, garnet, zircon). These are partly associated with the Mesozoic series inside the depression and partly—judging from the large size of the grain and their development up to the trap plateaux of the Central Siberian tableland—with rocks which in the pre-Quaternary time had overlain the trap covers on the Siberian platform and in the Byranga Mountains, and were afterwards washed away by the elevation of those areas during the Quaternary.

At the base of the Quaternary deposits of the Taimyr depression lie glacial deposits — boulder loams up to 17 m thick, exposed 40—60 m below sea level by a hole at the Kommunarka station (east of Dudinka), and composing also the highest monadnocks inside the depression (Ushkan-Kamen, Tass-Gherbei in the Dudypta basin, *etc.*). The products of a washing of the moraine, in the form of an areno-boulder-pebblestone horizon up to 30 m thick, underlie, as a rule, all the other Quaternary sediments, both in the holes (Ust-Yenissei port, Dudinka), and where pre-Quaternary rocks are exposed at the surface. The relatively high content in the moraines belonging to this first glaciation known to us, of boulders of Taimyr granitoids reaching as far as the northern slopes of the Central Siberian tableland, is evidence of the existence of a great centre of glaciation in the North Taimyr. It appears that the ice covered the whole of the Taimyr depression, reach-

* The Taimyr depression is a hollow situated between the mouths of the Yenissei and the Khatanga and filled with a thick layer of Mesozoic and Quaternary sediments. Morphologically, this is a lowland towards which steeply descends from the south the Central Siberian tableland, and from the north, the Byranga Mountains. Investigations carried out by the author in 1939/1942 refer to the western part of the depression (the basins of the Yenissei and the Pyassina).

ing far west and south beyond its boundaries. In the moraines of Ushkan-Kamen fragments of shells of *Saxicava arctica*, *Mya truncata* and *Tellina calcarea* are encountered, which is evidence that before the first glaciation the Quaternary sea penetrated far into the depression.

The glacial deposits in the holes of Ust-Yenissei port and of Kommunarka are overlain by a series of sands, 30—74 m thick, containing platy intercalations and pebblestone bands and lying below the level of the present rivers. These sands seem to have been deposited by the rivers that appeared in the depression after the maximum glaciation, when the base level of erosion lay still lower than at present. Upon their eroded surface rest marine deposits—mainly loams and clays up to 40 m thick (the Sanchugov horizon—layers with *Portlandia lenticula*).

According to their fauna (*Portlandia lenticula*, *Arca glacialis*, *Astarte crenata*, *Neacra arctica*), the rocks considered are sediments of a comparatively deep-water Arctic sea (of the order of 100 m). The rocks are found to contain large accumulations of pebbles and boulders that seem to have been washed out from the older glacial deposits. The Sanchugov strata are very extensively developed both on the Yenissei and its tributaries, and in the basin of the Pyassina and further eastward. It seems that during the Sanchugov epoch the sea covered nearly the whole of the Taimyr depression. Upwards the Sanchugov deposits give way to sediments of the Kazantzev horizon (layers with *Cyprina islandica*), usually represented by sands and sandy loams up to 20—30 m thick. In the basin of the Yenissei, as well as north of the 72nd parallel and in the basin of the Pyassina, these rocks contain marine, shallow-water, though thermophilic fauna (*Cyprina islandica*, *Balanus hameri*, *Balanus balanoides*). On the contrary, in the southern portion of the depression, within the basin of the Pyassina, near-shore lagoonal and alluvial facies of the Kazantzev horizon are developed containing a large quantity of vegetable remains, in particular trunks of large trees. The Kazantzev deposits extend also to the area of the Byranga Mountains, where corresponding to them is the maximum transgression of the Quaternary sea, reaching absolute marks of 160—200 m and also accompanied by the appearance of boreal and boreal-subarctic faunistic elements (*Pecten islandicus*, *Punctureilla noachina*, *Balanus hameri*).

Near the edge of the Byranga Mountains and at the foot of the Central Siberian tableland the Kazantzev layers rest upon the eroded surface of the Sanchugov clays, while inside the depression the two horizons are connected by gradual transitions.

The Kazantzev deposits pass upward without any break to a series of sands with bands of pebblestones and loams, with accumulations of boulders (the Zyriansk horizon). This series, having a thickness of 20—30 to 100 m, composes from the surface the water-divide areas throughout the Taimyr depression. The roof of the Zyriansk sands is distinguished by its highly undulating relief, which causes the appearance on the divides of hilly (of the type of kames) landscapes and seems to have been produced by an accumulation of sediments. The sands are generally devoid of vegetable remains, but at some points in the lower course of the right-hand side tributaries of the Pyassina—the Tareia and the Yangoda, and on the divide of the Pyassina and the Yenissei, a marine fauna (mainly *Saxicava arctica*) has been discovered. In the upper course of the Pyassina at the southern edge of the depression, fresh-water molluscs are present in the Zyriansk deposits. Finally, on the Yenissei the strata which are transitional layers from the Kazantzev to the Zyriansk horizon, are characterized by a brackish-water fauna (*Tellina baltica*). In the marginal parts of the depression, at the foot of the Byranga Mountains and the Central Siberian tableland, the Zyriansk sands are substituted by typical glacial deposits—ungraded boulder loams and sandy loams, not infrequently with inclusions of fossil ice.

It is to be presumed that the Zyriansk horizon was being formed at an epoch when glaciers which were in contact with the sea occupying the depression, descended to the Taimyr depression from the north and south. The level of the sea, as judged from the marks of the roof of the Zyriansk deposits (from 160 to 180 m), lay very high. This is confirmed also in the area of the Byranga Mountains

(E. M. Lutkevich). The fact that the Zyriansk basin is poor in fauna is explained by the action of glacial streams, freshening and contaminating the water by terrigenous particles, and also depositing the removed morainic material in the form of irregular heaps (kames).

Leaning against the divide plateaux in the Taimyr depression is an accumulating terrace 15—45 m above the sea level, largely composed of marine deposits, in the southern part of the depression substituted by alluvial deposits. According to data of drilling on the Yenissei, the bottom of the terrace formation lies 30—35 m below the level of the recent rivers, which is evidence of a considerable erosion that preceded the accumulation of the terrace. The sediments of this terrace which will be named here the Karga terrace, are represented by a highly variable complex of sands, loams and sandy loams, not infrequently with pebbles and boulders with a large quantity of tree trunks, with peat intercalations, and remains of *Elephas primigenius*. The very rich marine fauna of molluscs, crustaceans, brachiopods, sea urchins and bryozoans found in the Karga deposits, points to a normal salinity of the basin in the middle part of the depression, and more favourable temperature conditions as compared to the modern Kara Sea. Along with Arctic species of animals, boreal (*Rhynchonella psittacea*, *Balanus hameri*) and boreal-subarctic forms (*Mytilus edulis*, *Pecten islandicus*, *Punctarella noachina*) are also encountered here. Further south, in the estuaries of the rivers discharging from the south, there existed a brackish-water fauna, in particular colonies of *Tellina baltica*. Lastly the alluvial facies in the southern portion of the depression are characterized by a fauna of fresh-water molluscs, which is also evidence of better climatic conditions. Judging from the development of the Karga deposits, a complicated system of sea straits and bays seems to have existed in the Taimyr depression, which caused the appearance of a whole archipelago of islands at the place of the Taimyr peninsula. The marks reached by the Karga transgression attain 70—100 m above the sea level on the coast of the Yenissei Bay; 50—60 m in the lower course of the Pyassina; and 30—40 m in the southern part of the depression. Still further south, within the dry land of the Karga time, large areas were occupied by alluvial plains, as well as by lakes, remnants of which have still survived (the Pyassiano, Norilsk, and number of other lakes). It is essential to note that the Karga terrace on the Yenissei, up to the latitude of the Ust-Yenissei port, is a sea terrace, and further south, an alluvial one; it extends far up the river, and seems to pass into the Krasnoyarsk terrace of the middle course of the Yenissei.

The retreat of the Karga sea coincided with the maximum northward progress of forest vegetation. Corresponding to this period in the Taimyr depression is an accumulation of large peat bogs with tree remains, as well as the formation on the rivers of the northern part of the depression and in Lake Taimyr (after F. G. Markov) of alluvial terraces enclosed in the Karga terrace, and enclosing a large quantity of tree trunks and roots. A further lowering of the base level of erosion resulted in an incision of the rivers nearly 50 m below the recent level (data concerning the Ust-Yenissei port). At the same time the climate became considerably worse, causing an accumulation of ground (soil) ice in the upper horizons of the Quaternary deposits all over the area of the basin. In the east in the basin of the Khatanga even firn fields appeared, overlying all the horizons of the Quaternary deposits, including the Karga horizon (after I. P. Lughinetz). They have survived until the present time as thick (up to 20 m) deposits of fossil ice and firns, directly underlying the soil mantle and thus being considerably younger than the last large glaciation. Later, in the river valleys of the Taimyr depression, there took place formation of the lower underflood plain terrace 8—16 m high, composed of alluvial sands and possibly corresponding to the 7—10 m sea terrace of the Taimyr coast. The next stage in the history of the depression was characterized by an accumulation of sediments of the first (flood-plain) terrace, the bench of which, owing to the still continuing elevation of the country, is being formed at the present time.

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HYDROGEOLOGY

ORIGIN, FORMATION AND MIGRATION OF NATURAL BRINES AND WATERS OF THE SALT DEPOSITS OF THE USSR

By A. I. DZENS-LITOVSKY

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1. Salt deposits are occurring in nature in the form of fossil salts (solid phase) and dissolved salts, or salt solutions, natural brines (liquid phase).

Three types of salt deposits are generally distinguished: (a) salt (mineral) lakes; (b) salt deposits of fossil salts (bedded deposits, salt domes, *etc.*); (c) salt springs of natural brines (natural outflows, drill-holes, wells, *etc.*).

All the types of salt deposits may be united in the genetic series of successive development: (1) salt lakes (embryonic type); (2) salt deposits of fossil salts (fully developed type); (3) natural brines of springs (over-developed type).

2. The brines represent the main source of salts of all salt lakes.

It is necessary to distinguish the surface brines that fill the lake hollow, and the bottom brines that fill the bottom chemical sediments and silt deposits of salt lakes. The bottom brines filling the silt deposits (mineral muds) are usually termed silt brines; while those filling the bottom salt sediments (newly settled, settled at an earlier period and bottom salt) are termed intercrystalline (intersaline) brines.

According to its origin, bottom brines in self-settled lakes usually represent residual mother brines formed upon the settling of sodium chloride or sulphate salts.

Besides, in rocks that are country rocks with respect to the lake sediments, brines and waters may occur under the lake or near it.

3. The bottom brines (intersaline and silt) are usually distinguished by their highly constant chemical composition and concentration. Changes in the contents of bottom brines occur through metamorphization with characteristic mineral formations only, as a result of chemical processes and recrystallization (Table 1).

4. All the deposits of fossil salts are chemical sediments of former continental and near-sea saline lagoons and lakes, with buried salts, silts, waters and brines, which had suffered any kind of chemical and physical alterations subsequent to their formation as a result of diagenesis.

5. The following main types of waters and brines, characterized by different water contents, chemical composition and physical properties can usually be distinguished in salt deposits. This is done, according to the position of the underground waters and brines with respect to the salt body. (a) Oversalt waters and brines circulate over the salt in the cover-rocks. They are responsible for the most intensive karst processes being most harmful in the operation of salt mines. (b) Lateral or near-salt waters and brines surround the salt deposits from the sides. They occur at the contacts of the salt with the rocks surrounding the salt

Types of Brines and Waters of Salt Lakes

Table 1

Surface brines and waters		Bottom brines filling bottom chemical sediments and silt deposits			
				Underground brines and waters of rocks surrounding bottom sediments and lake brines	
Surface brine of lake hollow	Surface brines and waters of water bodies surrounding lake	Bottom silt brines	Bottom intercrystalline (intersalt) brines	Lateral (near-lake) brines and waters	Underlake brines and waters
According to Mineralization and Chemical Composition					
1. — 2. Brackish 3. Saline 4. Brine } Combination of all main anions and cations	1. Fresh 2. Brackish 3. Saline 4. Brines } Combination of all main anions and cations	1. — 2. Brackish 3. Saline 4. Brines } Combination of all main anions and cations; high content of Cl, Ca, Br and I; absence or insignificant content of SO_4. For salt lakes high Br content	1. — 2. Brackish 3. Saline 4. Brines } Combination of all the main anions, highest Mg and Ca content, high concentration of K and Br, with a lesser amount of Na and an absence of SO_4; a high spec. gravity	1. Fresh 2. Brackish 3. Saline 4. Brines } Combination of all main anions and cations	1. Fresh 2. Brackish 3. Saline 4. Brines } Combination of all anions and cations
According to Origin					
1. Local 2. Affluent 3. Mixed	1. Local 2. Affluent 3. Mixed	1. Local 2. Affluent 3. Mixed		1. Local 2. Affluent 3. Mixed	
According to the Mode of Occurrence					
Lake	Lakes, brooks, springs	Interveinal capillary pores	Fissures, caverns, pores, voids, intercrystalline spaces, *etc.*	Edge, fissure, artesian waters	Edge, fissure, artesian waters

Types of Waters and Natural Brines of Salt Deposits of Fossil Salts

Surface waters and surface natural brines		Underground waters and underground brines			
Oversalt	Lateral	Oversalt	Lateral	Undersalt	Intersalt (infrasalt)
According to Mineralization and Chemical Composition					
Combination of all main anions and cations	1. Fresh, waters with a total content of salts below 0.1 weight % 2. Brackish, » » » » » » from 0.1 to 3.5 » 3. Saline, » » » » » » » 3.5 » 26 » 4. Brines, saturated salt solutions » » 26% and over			Combination of all main anions and cations; a rather high content of Cl, Ca, Br and I; an absence, or insignificant content of SO_4	1. — 2. Brackish 3. Saline 4. Brines } Combination of all main ions: high Mg and Ca content, rather high content of K and Br, with a lesser amount of Na and absence of SO_4; a high spec. gravity
According to Origin					
	1. Local—atmospheric, condensation, infiltration waters 2. Affluent—underground, spring, river, brought from outside the salt deposit 3. Mixed—local and affluent				1. From oversalt, lateral and undersalt waters and brines 2. From residual brines 3. From old mother liquors 4. From mixed waters and brines
According to Mode of Occurrence					
Lakes, brooks, springs	Karst, fissure, edge waters				Karst voids, fissures, caverns, pores *etc.*

deposit, and may be confined to the most different rocks. (c) Under-salt waters and brines occur in rocks under the salt deposit. According to their origin, the undersalt and intersalt brines can represent ancient mother liquors buried under the salt during the settling of the latter.

6. The undersalt brines may be formed by diagenesis from the buried silts of saline lagoons and lakes. Under certain geological conditions undersalt brines and waters may form also at the expense of oversalt and wall waters. Lastly, undersalt waters may have no connexion whatever with the waters of the salt deposits, and their area of supply may lie far beyond the boundaries of the salt deposit.

The possibility is not excluded that in some particular cases undersalt waters and brines may rise along fractures in the salt deposits or along the sides of the deposit. In the former case they will serve to feed and form intersalt waters; in the latter case, wall rocks.

7. Investigations and observations made in underground workings of the potassium mines of Solikamsk and salt mines of Iletzk (Donetz Basin) and those in other countries, make it possible to differentiate intersalt or intrasalt waters. Intersalt waters and brines may be of different origin.

The intersalt waters usually represent isolated centres of saturated mother liquors, bottom salt sediments, «trapped», «squeezed out and sealed» in the course of formation of the salt deposit. The feeding of intersalt waters may proceed also at the expense of undersalt underground waters rising along the tectonic fissures in the salts.

8. From their chemical composition, the intersalt waters, referred by the author to the type of the so-called mother or primary liquors, are distinguished by a very high Mg content, a rather high concentration of K and Br, a lesser amount of Na (as compared to oversalt waters), and by a high specific gravity.

According to their origin, in the Soviet and foreign salt-mines the following types of intersalt waters may be distinguished: (a) intersalt waters representing primary mother liquors (Urlaugen); (b) intersalt waters representing residual brines (Restlaugen); (c) intersalt waters representing oversalt and lateral waters; (d) intersalt waters of a condensation origin.

9. Mother liquors (Urlaugen and Restlaugen) are saturated solutions. They often contain considerable amounts of sodium chloride, magnesium, calcium, and are rather high in potassium and bromine. Ejections of mother liquors observed during drilling for salt are generally accompanied by an evolution of hydrogen sulphide.

There are two kinds of mother brines: (a) mother liquors containing chiefly sodium chloride; (b) mother liquors containing magnesium chloride.

Intersalt brines of a mother-liquor origin are characterized by a constant chemical composition (Table 2).

10. When underground mining of potassium salts and rock salt is carried on, as well as when natural brines of salt deposits are worked for the chemical and salt industries, of particular interest is the regime of the waters and natural brines of the salt deposits.

At the salt mines of all countries, not excepting those of the Soviet Union, quite important amounts of money are annually spend to control the harmful activity of waters and natural brines.

11. Of great importance for a normal work of salt mines is a close acquaintance with the nature and conditions of all the waters and brines of the salt deposit, whose work tends to wash away and dissolve the salt deposit, causing sink-phenomena over the surface of the salt body, and being a continuous threat of flooding to the underground mine workings.

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GENETICS

MEIOTIC ABNORMALITIES IN HOPS INDUCED BY ATMOSPHERIC ELECTRICITY

By I. N. HOLUBINSKY

(Communicated by A. A. Richter, Member of the Academy, 29. V. 1944)

Very little breeding work has been done with hop (*Humulus Lupulus* L.) until recently. Intraspecific variation is, therefore, slight in this plant. It is to be assumed that, just owing to the scarce breeding work and in connexion with the fact that man had intervened but very little with the life of the hop plant (2), this species stands apart from the rest of species and steadily transmits its characteristics without crossing with other species, either in nature or under artificial conditions; in contrast to other species, it is not segregated into clearly distinguishable forms. All the physiological, biochemical, cytological and other processes go on in hops in the one and the same direction, without being materially disturbed in different forms of the species.

In particular, neither the present writer, nor other students could, so far we are aware, observe any disturbances in the reduction division in normal plant of *Humulus Lupulus*, save for meiosis in monoecious plants which eventually appear in hop plantations (1, 3).

The more interesting is the event observed by the writer, namely, the considerable disturbance of the course of reduction division caused by a violent thunder-storm that took place at the time of the blooming of the male plants of hop.

A small plantation consisting of male and of monoecious plants was planted for breeding purposes several years ago at the Ukrainian Station for hop research. In the course of our studies on the cytology and embryology of the normal male plants and of the monoecious plants we failed to notice during several years any abnormalities of the reduction division in the normal male hop plants (1). The greater was our surprise when we have found in a lot of slides numerous instances of abnormal meiosis in the pollen mother-cells. Careful investigation has proved that all the slides showing abnormalities were prepared of a material which was fixed the next day after a violent thunder-storm in July. All the other lots of material, *viz.* that were fixed the day prior to the thunder-storm, or those which were collected during several days subsequent to the storm, showed no abnormalities; abnormal meiosis was found only in those cells which passed meiosis at the time when thunder-storm broke out. In the material which was fixed several days after the thunder-storm, abnormalities of the later developmental stages were observed. This should be taken to testify that the cause of the abnormalities observed was operative earlier (*i. e.* at the time when thunder-storm had taken place). We were justified by this fact in our assumption that the cause of strong meiotic disturbance was the violent thunder-storm that took place the day prior to fixation.

The abnormalities consisted, in the first place, in mass instances of chromosome lagging (Figs. 1 and 2) and in the formation of abnormal pollen-grains with chromosomes that extruded into the cytoplasm (Fig. 3). The examination of the pollen-grains has shown considerable variation in their size (Fig. 4), which undoubtedly was additional evidence for abnormalities taking place in the course of

Fig. 1. Abnormal disjunction of chromosomes at anaphase of reduction division, as induced by atmospheric electricity

Fig. 2. Lagging of chromosomes at spindle under influence of atmospheric electricity

meiosis. The examination of the pollen-grains of the earlier maturing plants, as well as of the later maturing ones failed to show any size differences. As we have not anticipated any phenomena of the kind described above, no serial fixations were made; otherwise the whole course of meiosis could be followed step by step after the intervention of the violent effect of the thunder-storm. It is noteworthy, however, that it is widely believed among the Czech hop growers that violent summer thunder-storms do often lead to mass destruction of aphids feeding on the hop plantations.

An explanation for the abnormalities described above should be sought in the special wire networks which densely cover the plantation. At the height of 6 m

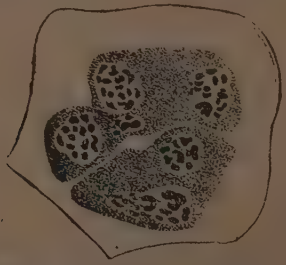

Fig. 3. Formation of abnormal (teratological) pollen-grains under influence of atmospheric electricity

Fig. 4. Gigantic pollen-grains among normal ones induced by atmospheric electricity

between posts a rather thick wire is stretched above every row of plants (1.6 m apart from each other); every 10 m the wires cross perpendicular wires, and thinner wires run down to every individual plant to support its climbing shoots. At the edges of the plantation there are oblique posts, fixed by thick wires fastened to anchors buried in the ground.

The whole arrangement, the wire network above the ground, traces to the anchors and wires leading to individual plants, form an excellent accumulator of electricity and a lightning conductor. It is rather dangerous to stay near the wire traces at the plantation, the more to touch them during a storm. Violent electric discharges should therefore lead to disturbances in the meiosis of the

kind observed by us in our preparations. Abnormalities found in the male gametophyte seem to take place in the female gametophyte, too.

The question may be raised, Why there is so little variation in hops despite its being grown on wire networks in the Volyn province, where summer storms are very frequent? The answer to this question is no embarrassing one. Hops are propagated vegetatively, by cuttings which are evidently not susceptible to the thunder-storm phenomena. Planting by seeds is practised only for breeding purposes; hybridization has not been applied, moreover, until recent years. All the seeds containing embryos modified by the thunder-storm phenomena usually die being unable to produce adult plants.

Our observations on the disturbances in the course of the reduction division induced by atmospheric electricity suggest the possibility of experimental induction of the same disturbances, in order to obtain mutant forms; this should be of great importance in the case of such a uniform plant as hop. Moreover, the plant being able to propagate vegetatively, it is possible to fix any mutation that may arise.

Ukrainian Hop-Research Station.

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ZOOLOGY

PERIODICITY AND CRITICAL STAGES IN THE LARVAL DEVELOPMENT IN THE BAIKAL OMUL (*COREGONUS MIGRATORIUS*)

By V. I. OLIPHAN

(*Communicated by I. I. Schmalhausen, Member of the Academy, 22. IV. 1944*)

As shown by the present author in 1938, the early post-embryonic development of *Acipenseridae* fish after the moment of hatching and the transformation of larvae into fry, consists of a succession of well delimited stages characterized by peculiar features of gas exchange, sensitivity, vitality and rate of growth of the larvae and of their morphological differentiation as well.

At the culminating points of development there is observed a leap-like variation of these features, accompanied by a decrease of physiological resistance to unfavourable environmental conditions. Those periods of abrupt changes affecting a number of characters have been termed by us critical stages of development.

During the summer 1942 ecological and physiological experiments were carried out at the Buryat-Mongol fish-culture station (on the river Bolshaya Rechka, tributary of Lake Baikal). The purpose of those observations was to ascertain whether the development of the Baikal omul *Coregonus migratorius* also obeys to this regularity.

In our experiments on the age variation of sensitivity the larvae were exposed to a temperature of 29° C during 5 minutes. The results of these experiments are shown in Table 1.

Table 1

Age Variation in Sensitivity

Age (days)	Percentage of loss (mean)	Number of larvae under experiment	Age (days)	Percentage of loss (mean)	Number of larvae under experiment
1	23.26	230	16	60	125
2	38	50	17	50.8	50
3	0	100	19	0	25
4	2	50	21	6.6	25
...	...	...	35	0	150
12	51	100	40	0	10
14	0.44	100			

Data concerning age variation in respiration have been obtained from our experiments on the respiration of omul larvae at the various stages of development. Oxygen consumption was determined by Winkler's method. The experiments were carried out at a temperature of 18° C. The results are summarized in Table 2.

Table 2

Age Variation in Respiration of Omul Larvae

Age (days)	O_2 consumption by 10 larvae (in mg per hour)	Respiration intensity	Mean respiration intensity
8	0.0490	0.597	
8	0.0458	0.581	0.573
8	0.0425	0.540	
9	0.00666	0.896	
9	0.00613	0.778	0.877
9	0.0755	0.958	
11	0.0847	1.106	
11	0.0833	1.018	1.000
11	0.0716	0.875	
12	0.0483	0.630	0.681
12	0.0565	0.732	
13	0.0314	0.434	0.434
14	0.0303	0.454	
14	0.0237		0.464
14	0.0151	0.473	
16	0.05739	0.861	0.805
16	0.05336	0.749	
17	0.5869	0.872	0.894
17	0.05998	0.916	
19	0.0244	0.388	0.466
19	0.0322	0.544	
22	0.470	0.280	0.230
22	0.1173	0.180	
32	0.5556	0.7716	0.922
32	0.3271	0.0720	

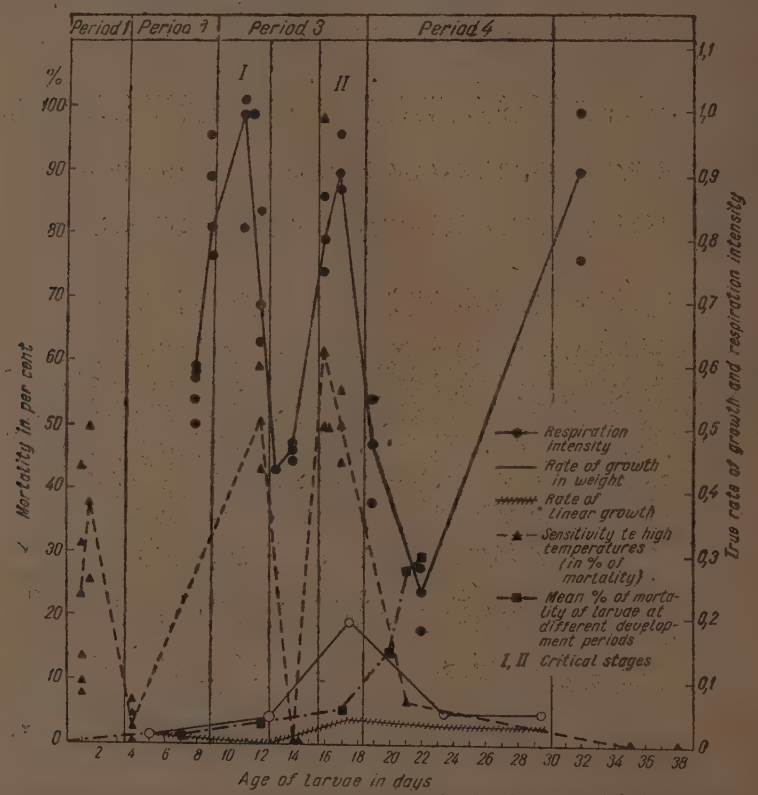
Table 3

Age Variation in the Rate of Growth

Age (days)	By length		By weight	
	length (mm)	rate of growth c_r	weight (mg)	rate of growth c_r
1	12.10		41.02	
10	12.50	0.0041	45.13	0.0119
15	12.60	0.0016	55.13	0.0400
20	16.00	**0.0478**	164.25	**0.223**
28	17.50	0.0390	310.11	0.0577
31	19.50	0.0361		

In order to evaluate the rate of vitality in omul larvae at different development stages, the experimental material was kept in containers at different densities of stocking, and records were made of the mean daily mortality for periods of 2—4 days. The survival curve (see figure) has been based on mean values computed for each of the eight containers.

The regularities underlying age variations in the rate of growth were studied on omul larvae from rearing ponds. Larvae caught from these ponds with a bag



Variation in sensitivity, respiration, vitality and rate of growth at different stages of development of omul larvae

net at five day intervals were measured under a magnifying glass and weighed on an analytical balance.

Table 3 contains the results of these measurements, as well as the true rates of growth (c_v) at different stages of development, computed from these data according to the formula of I. I. Schmalhausen(1): $c_v = \frac{\lg \varphi_1 - \lg \varphi}{(t_1 - t)\,0.4343}$.

Discussion. The investigations performed permit to characterize the early post-embryonic ontogenesis of *Coregonus migratorius* in the following way.

During the period from hatching to the age of 3—4 days when the yolk-sac is still well perceptible, the larvae are very sensitive to high temperatures, though the degree of sensitivity varies within a fairly wide range. This rate of survival is a high one.

The period from the 4th to the 10th day, during which the yolk-sac becomes wholly resorbed and the larvae start active feeding, is characterized by a general

decrease in life activity, affecting also the rate of growth. The larvae are resistant to high temperatures; their rate of survival is high still.

At the age from 10 to 19 days, period of differentiation of internal organs and beginning of transformation into fry, an abrupt rise is observed in the susceptibility to high temperatures. The rate of growth increases especially towards the end of this period, whereas the vitality decreases, so that under unfavourable conditions the losses in larvae may run into rather high figures.

At the next stage of development—age of 19—30 days—the process of formation continues: the ventral fins are formed as well as the rays of the differentiated unpaired fins. The intensity of growth is high, though lower than during the preceding period. The resistance to high temperature increases.

Upon a close examination of the data tabulated above, the stages of 9—12 days and 16—17 days are found to be characterized by sharp increases in the intensity of respiration and susceptibility to high temperatures. Furthermore at the age 16—17 days we observed an abrupt increase in the rate of mortality (by 62 per cent) and in the rate of growth (by 82 per cent).

Both these stages which correspond to the transition of the larvae from one stage of development to another, and are characterized by a greater lability of several physiological processes, as well as by a better resistance to unfavourable conditions, may be termed the critical stages.

Thus, an analysis of age variation in the early post-embryonic development of the omul reveals the presence of periodicity and of critical stages in this development.

The high mortality in salmonid larvae reared at hatcheries in the USSR and abroad is undoubtedly connected with the existence of critical stages of larval development.

Further study of these stages is necessary in order to gain a clearer idea of the causes of mass mortality in omul larvae at definite periods of development, and to work out means to prevent losses in the course of rearing.

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EXPERIMENTAL MORPHOLOGY

CHANGES IN CONNECTIVE-TISSUE CELLS IN THE CASE OF REGENERATION. III

By T. M. YAKOVLEVA

(Communicated by L. A. Orbeli, Member of the Academy, 29. IV. 1944)

In my preceding communications ([1], [2]) I have described a gradual transformation of connective-tissue fibroblasts of the fin part of tail in axolotl into cells of a regeneration blastema of embryonic type. As indices of transformation were chosen the gradually increasing quantities of pentosonucleic acid substances contained in their cytoplasm, and the gradual change in the physical-chemical state of those substances, evaluated by their failure to coacervate in the form of granules under the influence of neutralrot. The regeneration of tail is an example of organ regeneration ([3]) which is inherent in a few classes of lower vertebrates only. In higher vertebrates regeneration ability is expressed in tissue regeneration only that is realized in all vertebrates in general in the same way ([4]). The regeneration of a skin wound in the region of the dorsal musculature in an axolotl may serve as an example of tissue regeneration.

The purpose of this investigation was to find out whether the process of tissue regeneration is accompanied with such fibroblast changes as are observed in the process of regeneration of a fin part of an axolotl tail.

Grey axolotls, no less than two-year-old, were used as a material for the present investigation. A wound 2×2 mm in size was made in the region of the dorsal musculature of each axolotl. 0.5 cm^3 of a 0.5 per cent neutralrot solution was injected three times at different intervals to each axolotl according to the method described by Chlopin ([5]). The material was fixed by the Birch-Hirschfeld solution. The sections were stained with azur-eosin after Nocht. Contrary to Chlopin's observations, a successful vital staining with neutralrot, with coacervation of crinome granulae, was but very rarely observed. Accordingly, out of the 14 experimental animals studied, only three could be chosen that showed most successful staining.

Axolotl No. 8 was fixed 29 days after the wound had been inflicted. The healing process at that time is at an early stage of differentiation of collagen fibres ([4]). In the centre of the wound an exudation is observable. The connective-tissue elements and collagen fibres in the process of intense formation arranged along the edges of the wound. All the connective-tissue cells present in the wound contain granules of pentosonucleic acid substances (crinome). In the centre of the wound are observable cells with an incomplete coacervation of pentosonucleic acid substances ([1]). Connective-tissue cells in the regions remote from the wound did not contain any granules at all.

The counting of granules was begun in such cells where their number was the lowest, and ended at the edges of the wound where an intense formation of fibrous structures was taking place. In this place were also observed cells very rich in pentosonucleic acid substances. In most of cases, the distance between such regions and the starting point of counting was 0.9 mm. Therefore, the whole area

studied could be divided into three equal sections, equal to 0.3 mm each. The granules were counted in every connective-tissue cell present between the epithelium and the dorsal musculature, by making camera lucida drawings for every cell. To make the results comparable with those obtained in the study of the tail regeneration, the numeration of intervals was begun from the edge of the wound. A variation curve showing the cell distribution within a given area in relation to the number of granules contained was made for each section (Fig. 1 and Table 1).

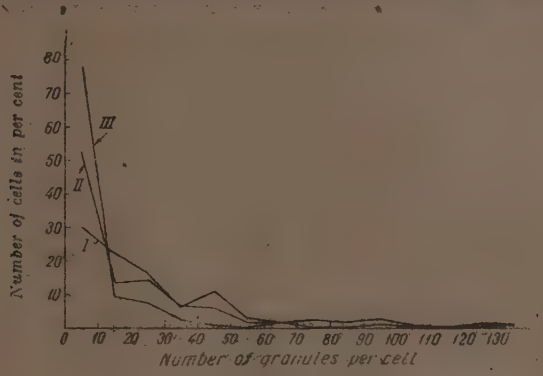

Fig. 1

Table 1

Regions	Distance from edge of wound in mm	N	$M \pm m$ granules	R_M	$\sigma \pm m_\sigma$ granules	R_σ	$E \pm m_E$
I	0.1—0.3	125	26.02±2.24	2.65	25.11±1.99	1.4	3.03±0.44
II	0.4—0.6	117	18.00±2.04	4.13	22.03±1.45	7.53	10.15±0.45
III	0.7—0.9	146	8.88±0.85		10.27±0.60		11.28±0.41

The variation curve corresponding to the section most remote from the wound (*III*) is unilateral in shape, and shows a great excess. The latter is due to the crowding of a great majority of variations around a mean value, showing that each cell of this region contains no more than 10 granules of pentosonucleic acid substances. According to the pentosonucleic acid substances contained in the cells the material shows a considerable uniformity ($\sigma = 10.27$ granules).

The curve *II* for the second section shows an increase in the number of granules up to 18 per cell. The variability is also increased. The material, in general, is less uniform, containing cells higher in pentosonucleic acid substances (up to 140 granules per cell). Accordingly, the left part of the curve is extended and the excess decreased.

The curve *I* for the first section corresponding to the edge of the wound shows scarcely any excess in shape. Still more numerous are the cells containing great numbers of granules ($M = 26.02$). The cell variability in the neighbourhood of the wound is also at its maximum here ($\sigma = 25.11$).

The variation constants considered demonstrate gradual changes in the subcuticular connective-tissue fibroblasts, just similar to those observed in regeneration of axolotl tail.

It is necessary to underline here the inverse relation between E and σ values: the nearer the region to the wound, the lower are E and the higher σ values. From the uniform connective tissue fibroblasts there arise regenerative cells varying as to the content and for the most part rich in pentosonucleic acid substan-

ces. This variability goes to confirm my earlier suggestion (2) that all the fibroblasts are not equally able to change under the influence of wound impulses, which depends upon the stage of cell development during the connective-tissue histogenesis.

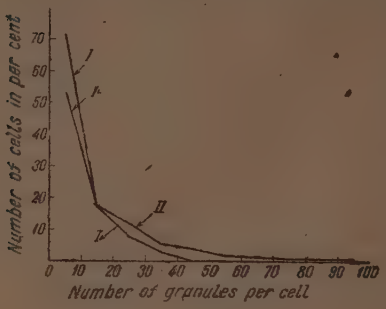

Fig. 2

In some of sections it was possible to count the granules in a region 0.3 mm apart from the wound (Table 2). The variation curve for this region shows some kind of the secondary decrease in the cell number with a high content of pentosonucleic acid substances, and a narrower range of variation. This fact finds its explanation in the assumption that in this region, as well as in the centre, there are present cells characterized by an incomplete coacervation of the crinome (1), *i. e.* a certain part of pentosonucleic acid substances of their cytoplasm is unable of coacervation under the influence of neutralrot, which results in a basophilous staining of the cytoplasm. It seems not amiss to suppose in this connexfon that the cells which are especially high in pentosonucleic acid substances are the first to lose their ability to coacervate, since these very substances are missing in the region in question.

In other respects the curve of the region considered is almost identical with that of the first one. The differences in the M and σ values, given in Table 2, are insignificant.

Table 2

N	$M \pm m$ granules	R_M	$\sigma \pm m_\sigma$ granules	R_σ	$E \pm m_E$
148	21.26 ± 1.61	1.72	19.56 ± 1.14	2.01	3.24 ± 0.40

Axolotl No. 7 was fixed 40 days after wounding. It was a very old specimen, and the rate of regeneration in this animal was so low as to correspond to that of No. 8 axolotl, which was fixed 29 days after wounding. There were great difficulties in studying this specimen because of the stronger staining applied. Therefore, its fibroblasts, even in the region of completely normal tissue, still contained a few granules of pentosonucleic acid substances. Accordingly, arbitrarily taken region 2.2 mm long was studied, which extended by one end to the edge of the wound and by another to the region characteristic for the normal tissue. The area studied was divided into two equal parts, and variation curves for the number of granules in the cells of either of them were plotted (Fig. 2 and Table 3). The results proved completely identical with those for axolotl No. 8.

The second problem was to find out, whether the fibroblasts, changing in the process of wound regeneration, reach the embryonic stage of cells at which these are unable to coacervate pentosonucleic acid substances under the influence of neutralrot. The wounds of the axolotls No. 7 and 8 already showed the beginning stage of tissue differentiation, at which, according to data available on the regeneration of tail fin, all the blastema cells secondarily become able to form granules. Accordingly, cells of embryonic type were necessarily to be looked for at an earlier stage of wound healing.

Axolotl No. 6 fixed 23 days after wounding may serve as an example of this kind. At the edge of the wound (Fig. 3, *c*) one may see cells that have bright nuclei without any chromatin structures on the fixed sections. Nucleoli are clearly seen, the protoplasm is an intense blue and does not contain granules. Somewhat apart

Table 3

Regions	Distance from edge of wound in mm	N	$M \pm m$ granules	R_M	$\sigma \pm m_\sigma$ granules	R_σ	$E \pm m_E$
I	0—1.1	403	16.29±0.90	6.69	18.01±0.64	14.48	3.57±0.24
II	1.2—2.2	176	8.93±0.63		8.31±0.21		5.79±0.37

from the wound (*b*) there are present cells containing darker nuclei with well-expressed structures and a brigther protoplasm, containing dark blue granules against a blue background. And lastly, still further from the wound (*a*) there

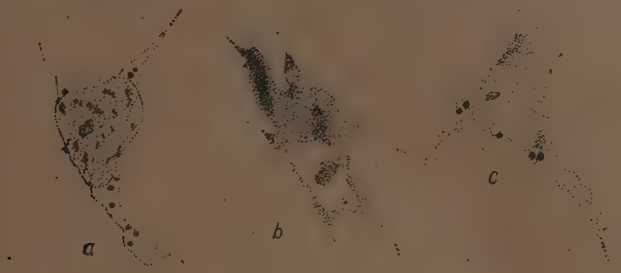

Fig. 3.

were found typical fibroblasts with rather dark nuclei and nearly colourless protoplasm against the background of which the granules of pentosonucleic acid substances could be clearly seen. Thus, we observe here a whole range of transitions, just like that observed in the case of regeneration of a fin part of tail. Nevertheless, it should be pointed out that in counterdistinction to tail regeneration, alongside of the cells that are unable to coacervate the pentosonucleic acid substances, one may see in the wound region such cells as show both complete and incomplete crinome coacervation.

Thus, in the process of regeneration of connective tissue in axolotl—a process which is peculiar to all vertebrates, the fibroblasts undergo the same range of transformations as during the exceptional and enigmatic process which is the regeneration of a whole organ.

According to Caspersson [6] the presence in the cytoplasm of pentosonucleic acid substances is always connected with intense protein synthesis. This permits us to suggest that the presence of a large amount of proteins is the essential characteristic of an embryonic cell, and a condition necessary for its further differentiation.

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PARASITOLOGY

CAUSES AND VALUE OF MIGRATION PHENOMENON IN *ASCARIS* LARVAE

EVOLUTIONARY WAYS OF BIOLOGICAL CYCLES OF DEVELOPMENT WITHIN THE ORDER *ASCARIDATA*

By I. M. VINNITZKY

(Communicated by I. I. Schmalhausen, Member of the Academy, 22. IV. 1944)

The peculiar phenomenon of migration of *Ascaris* larvae was described by Stewart as early as in 1916. Later on it has been studied in detail by a number of authors in various countries. Among these special credit belongs to Fülleborn (4) who gave this phenomenon a correct interpretation, and also to Ransom and Cram (6). The causal and phylogenetic aspect of the problem could not fail to attract the attention of specialists. The migration of the *Ascaris* larvae seems to be still more enigmatic, by dint of its apparent inexpedience, if we are to consider that during this complicate and unnecessary travel an elimination of larvae takes place, for large numbers of them become incapsulated in the internal organs of the host, where they are absolutely harmless to the latter. But a few of the larvae succeed in achieving their migration cycle, *i. e.* to penetrate again into the alimentary canal of the host; after having been «biologically remodelled», they are now able to settle at an appropriate section of the intestine and to attain sex maturity, whereas the larvae that hatched from eggs have actively to «bore» their way through the intestinal wall, for otherwise they will be eliminated by the peristaltic movements of the intestine.

The results of our studies make it evident (5) that quite important numbers of migrating larvae become eliminated. Thus, after 20 000 invasion eggs of *Toxocara cati* had been fed to young cats, even in those of them which were kept on a vitaminless diet the number of the nematodes in the intestine varied from 75 to 231, while in the animals kept on a diet supplemented with a vitamin calcium preparation, this number was as low as 0—25.

An important amount of work in this line has been done by Smirnov (7); without expressing any opinion of his own as to the possible cause of migration, this writer remarks that «the deciphering of the peculiar migration ability of certain nematodes should be classed among such important biological problems as are still at a stage of hypotheses».

The migration was interpreted as a «flight reflex» which makes a young larva hastily leave a medium (intestine) which does not agree with it (1). It was also put down to the necessity of glycogen accumulation in the lungs (3), or by the requirement of the larvae for blood proteins (2), *etc.*

The theory that has been almost generally adopted is that of «phylogenetic reminescence» as a result of the failure of the one of the two hosts the ancestors of the *Ascaridae* allegedly possessed. This theory was formulated as far back as in 1927 by Fülleborn who persistently developed it in his subsequent papers, be-

ing supported by Wülker (3) and Cameron(2). But it can hardly withstand any sound criticism for a number of causes.

We are inclined to believe that *Ascaridae* owe their origin to a form whose larvae infested their hosts percutaneously, which is still characteristic of a large number of nematodes. In the course of evolution those parasites developed more perfect protective adaptation in embryo and larva, which led to a formation of very resistant egg-walls. Owing to this, the larvae ceased to leave the eggs, and the passive infestation of the host *per os* has become obligatory.

We thus arrive at a phylogenetic interpretation of the origin of migration of the *Ascaris* larvae as an inherited tendency actively to penetrate upon hatching into the tissues of the host. Let us point out in order to substantiate our interpretation that the percutaneous mode of infestation which is necessarily leading to a hematogenous migration of the larvae, was not only inherent in the ancestors of the recent *Ascaridae*, but has not been fully lost by them at this epoch, either.

Is should be noted that the very process of migration which seems primarily to have been but a way to penetrate into the organism of the host, has later on been transformed into a physiological impulse (the requirement of larvae to feed on blood plasm); this is largely why it was not omitted from the life cycle of the *Ascaridae* after they had passed to a passive mode of infestation (with eggs).

It is during the complex process of migration of *Ascaris* larvae that the struggle between the parasite and its host comes to its decisive stage. To the activity of the larvae that are boring their way through its internal organs, the organism of the host responds by a typical defensory reaction. The latter leads ultimately to a complete incapsulation of a considerable part of the migrating larvae in connective tissue. And this means the «victory» of the host, for the travelling larvae are thus captured, entombed, and cannot possibly attain their sex maturity in the host's organism.

We have elsewhere suggested the idea that the struggle between the two components of the system «parasite — host», which went on during a very long period of time, led to an adaptive capacity of the parasite to neutralize the defensory reaction of the host—the incapsulation—and even to turn it to good profit. Occasionally this defensory reaction of the host transforms into a condition necessary for the parasite in order to go through its life cycle. To prove this assumption we had recourse both to experimental data and to observations on the development cycle of various nematodes.

In the process of evolution the larvae seem to have developed, and to develop still, certain adaptations that tend to neutralize the detrimental action of phagocytes, enzymes and humoral agencies. Owing to this, the larvae remain for a long time alive even if entirely incapsulated, and, as has been shown experimentally, such incapsulated larvae may serve as a source of infestation. Consequently, any organism containing larvae, either at a state of migration, or incapsulated in connective tissue, may be a potential intermediate host. Such potential intermediate (facultative) hosts are known to exist in other nematodes, too. Thus, for example, a non-obligatory change of hosts has been reported for *Syngamus trachea* (Montegu, 1871) and *Physocephalus sexalatus* (Molin, 1866).

The existence of potential intermediate hosts raises the chances of the parasite in its struggle for existence considerably. In *Ascaridae* the chances to succeed are still more enhanced by the fact that, while showing in the sex-mature stage a well-pronounced specific affinity for definite hosts, they show no such specificity at the larval stage.

Thus, for example, the swine, which is the direct host of *Ascaris suum*, is at the same time a potential host of the same parasite. But along with the swine, as a potential host of *A. suum* may also act any mammal, including rodentia, on which the swine may occasionally feed. It need not be stressed that the phenomenon here discussed, which contributes to the distribution of the parasite, is a highly important adaptation.

In *Ascaridae* of the same order *Ascaridata*, but parasitic of chicks, pigeons and other birds, which cannot become infested by devouring other vertebrates,

the migrational cycle of development that had primarily been inherent in them proved useless, and disappeared therefore in the course of evolution. Thus, for example, *Ascaridia lineata* (Schneider, 1868) does not migrate, as a rule, in the organism of chicks along the blood flow, but goes through its early stage of development in the Brunner glands, after which the parasites are eliminated into the lumen of the intestine. In exceptional cases, however, the migration phenomenon may take place.

The phenomenon here described for *Ascaris suum* is in this case, as in the case of any *Ascaris* parasitic of mammals, a mere adaptation, contributing to a further spread of the parasite. But under specific habitation conditions of the host it may become a condition without which the parasite cannot exist in nature.

The seal which is largely an aquatic animal, is running scarcely any risk of swallowing eggs of *Porrocaecum desipiens* (Krabbe, 1878), family *Anisakidae*, which are excreted together with its own fecalia. But fishes which may occasionally feed on the latter are liable to do so. In this way the intermediate hosts, sea fishes, into whose internal organs the larvae migrate and become incapsulated, become the only source of infestation of sea mammals with *P. desipiens*. An analogous picture is observed in *Anisakidae* of sea birds and sea fishes.

Thus, we are led to conclusions which are in full disagreement with those of Fülleborn and, consequently, of Wülker and Cameron, too.

The evolution of *Ascaridata* did not proceed by way of «omission» of the one of the two hosts, but, on the contrary, by way of «including» into their life cycle intermediate facultative hosts, in the form of various terrestrial mammals (in the family *Ascaridae*), or obligatory hosts, in the form of fishes for sea mammals and sea birds (in the family *Anisakidae*).

If there is no chance of infestation through the vertebrate intermediate host, as, for example, in the case of chicks, pigeons (in the family *Ascarididae*), the migration of larvae disappears in the process of evolution, being obviously useless.

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